72275

DRAFT

Fragmental Polymict Breccia

3640 grams

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Figure 1: Photo of pieces of 72275. Note thin patina and surface exposure of "Marble Cake" clast. NASA# S73-16077. Scale and cube in cm.

Introduction

Lunar sample 72275 is a friable feldspathic breccia with an aphanitic matrix and several important clasts (figure 1). It was collected from the top of a layered boulder (#1), located within a landslide from the South Massif at the Apollo 17 site (Marvin 1975, Schmitt 1975) and is generally thought to represent ejecta from the Serenitatis basin (Dalrymple and Ryder 1996) (however, see evidence to the contrary in the paper by Morgan et al. 1975). The boulder may have rolled down the slope of the South Massif after the emplacement of the landside, but there are no boulder tracks visible today so it is difficult to tell where exactly it came from (Wolfe 1975).

72275 was specifically collected from boulder 1, because it appeared to be representative of the matrix of the boulder. It was found that the chemical composition of 72275 matrix had higher trace element content than for the other three samples of this boulder (figure 2). This sample has a wide variety of clast types derived from the lunar highlands (Stoeser *et al.* 1974, Ryder et al. 1977, Salpas et al. 1987, 1988). It has a high trace element content due to a high abundance of KREEPy non-mare basalt. It doesn't contain any of the high-Ti mare material from the valley floor and is not a regolith breccia. The matrix and many of the clasts contain significant Ir and Au contents indicating

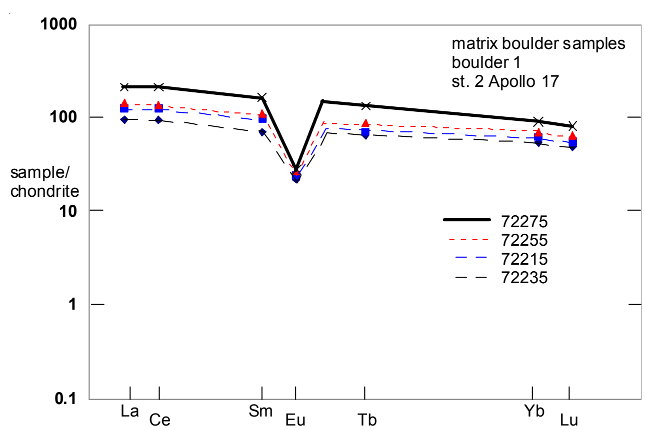

Figure 2: Composition of matrix of 72275 with that of other samples from same boulder (#1). Data from Blanchard et al. (1975).

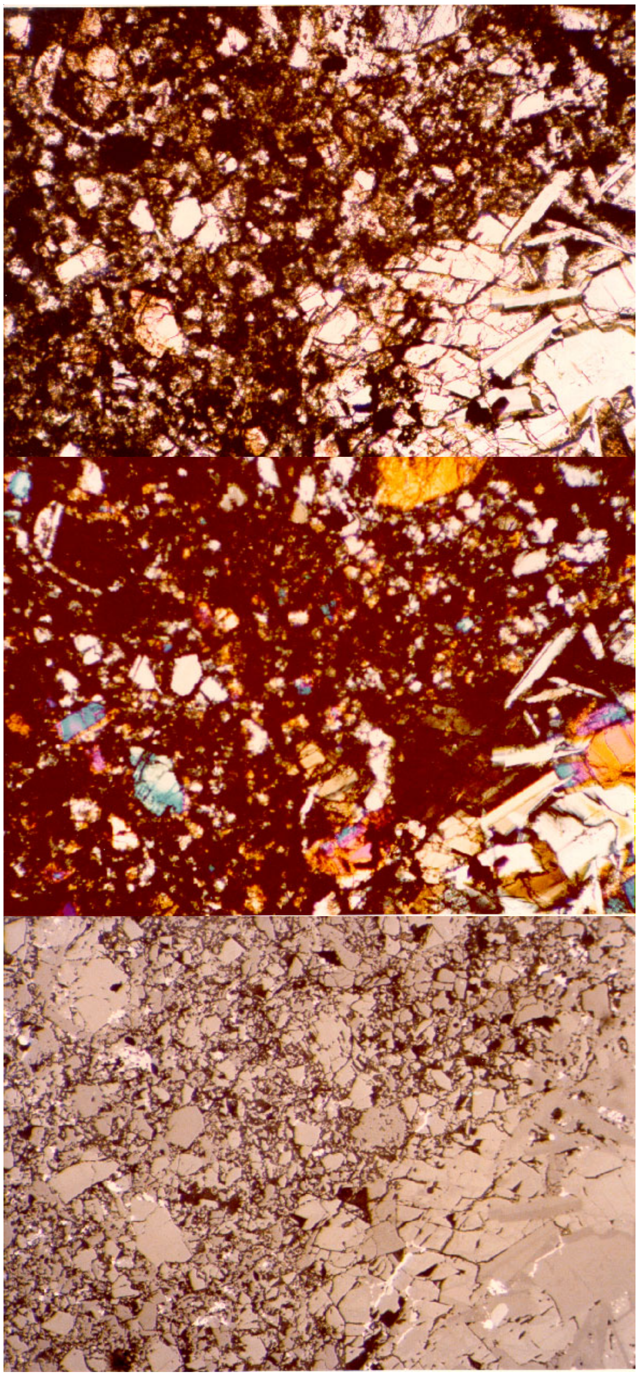

Figure 3: Photomicorgaphs of same area of thin section 72275,148: a) transmitted light, b) polarized light, c) reflected light. Note basalt clast in corner. Note also the porosity of matrix; best seen in reflected light. Scale is 1.4 mm across.

meteorite contamination. It is clast rich and somewhat akin to the Apollo 14 breccias.

This sample has a breccia-in-breccia texture where clasts of darker microbreccia are included in the light feldspathic matrix (figure 4). The major mineral in the matrix is feldspar. The darker areas have a higher

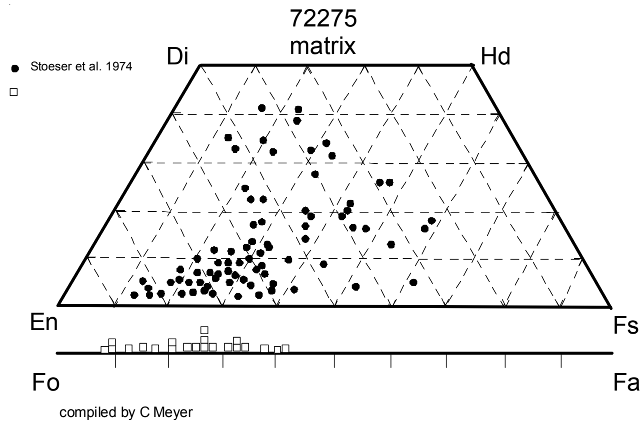

Figure 4: Pyroxene and olivine compositions in matrix of 72275 (from Stoeser et al. 1974 and Ryder et al. 1975).

percentage of fine matrix to clasts (Willis 1985). Portions of the light friable matrix of sample 72275 are very porous (5 to 30 percent).

72275 was the object of study by the "Consortium Indomitabile" (John Wood, leader) and of the "breccia-pull-apart" study by Larry Taylor (Salpas 1985). Ryder (1993) provides a comprehensive review of all aspects of 72275.

Petrography

72275 is a polymict breccia with about 60% light porous matrix and 40% clasts. The majority of the clasts are dark aphanitic microbreccia, but also include non-mare basalt and feldspathic, plutonic fragments of the lunar crust. The light matrix of 72275 is a porous aggregate of angular mineral and lithic fragments ranging in size up to 0.1 mm (Marvin 1975). Calcic feldspar (An_{92-98}) is the dominant mineral phase. The

Clast Population 72275 (from Stoeser et al. 1974)

Granulitic ANT breccias	48 %
Granulitc polygonal anorthosite	3.5
Crushed anorthosite	5.1
Devitrified glass	7.9
Glass shards	0.4
Ultramafic particles	1.6
Basaltic troctolite	2.0
Pigeonite basalt	5.1
Other basaltic	2
Granite	1.6
Norite	0.4
Plagioclase	15
Mafic minerals	5.5
Opaques	1.2

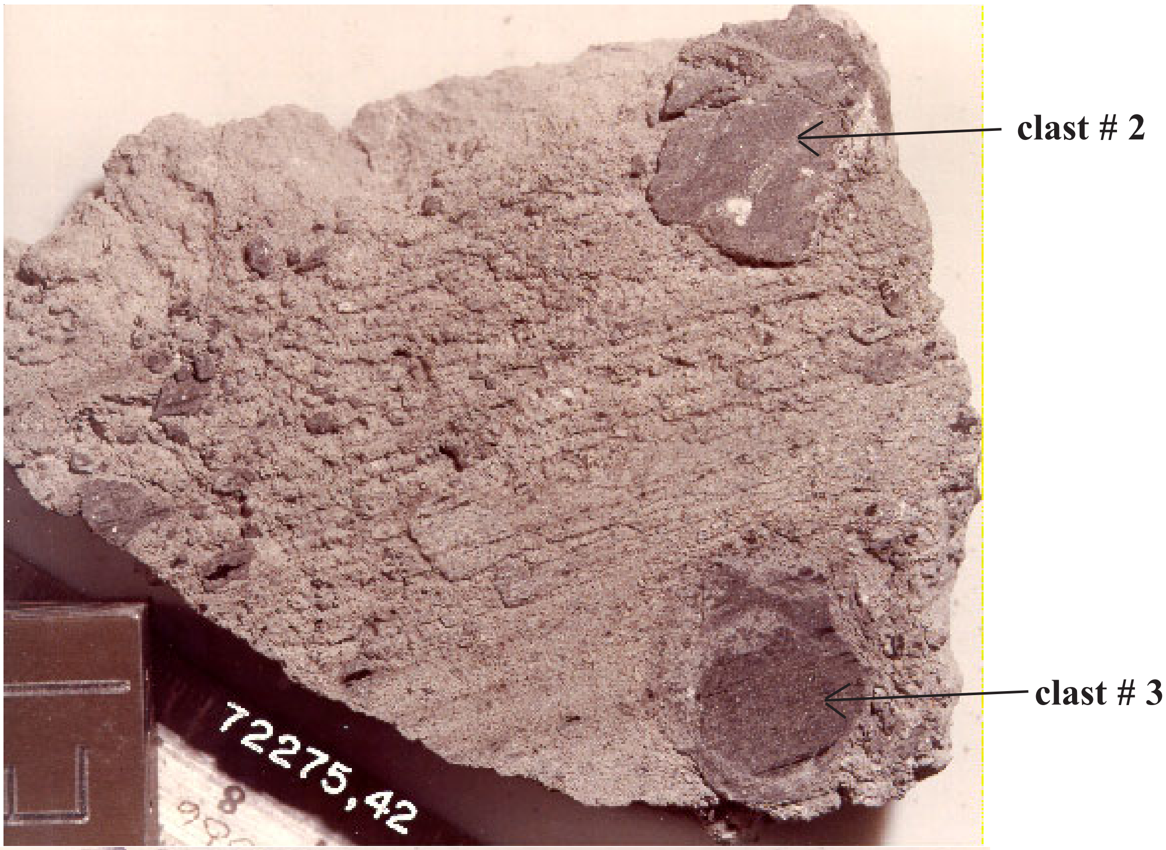

Figure 5: Front and back of first slab (,42) cut from 72275. NASA# S73-32623-32624. Cube is 1 inch.

clast #1 “Marble Cake”

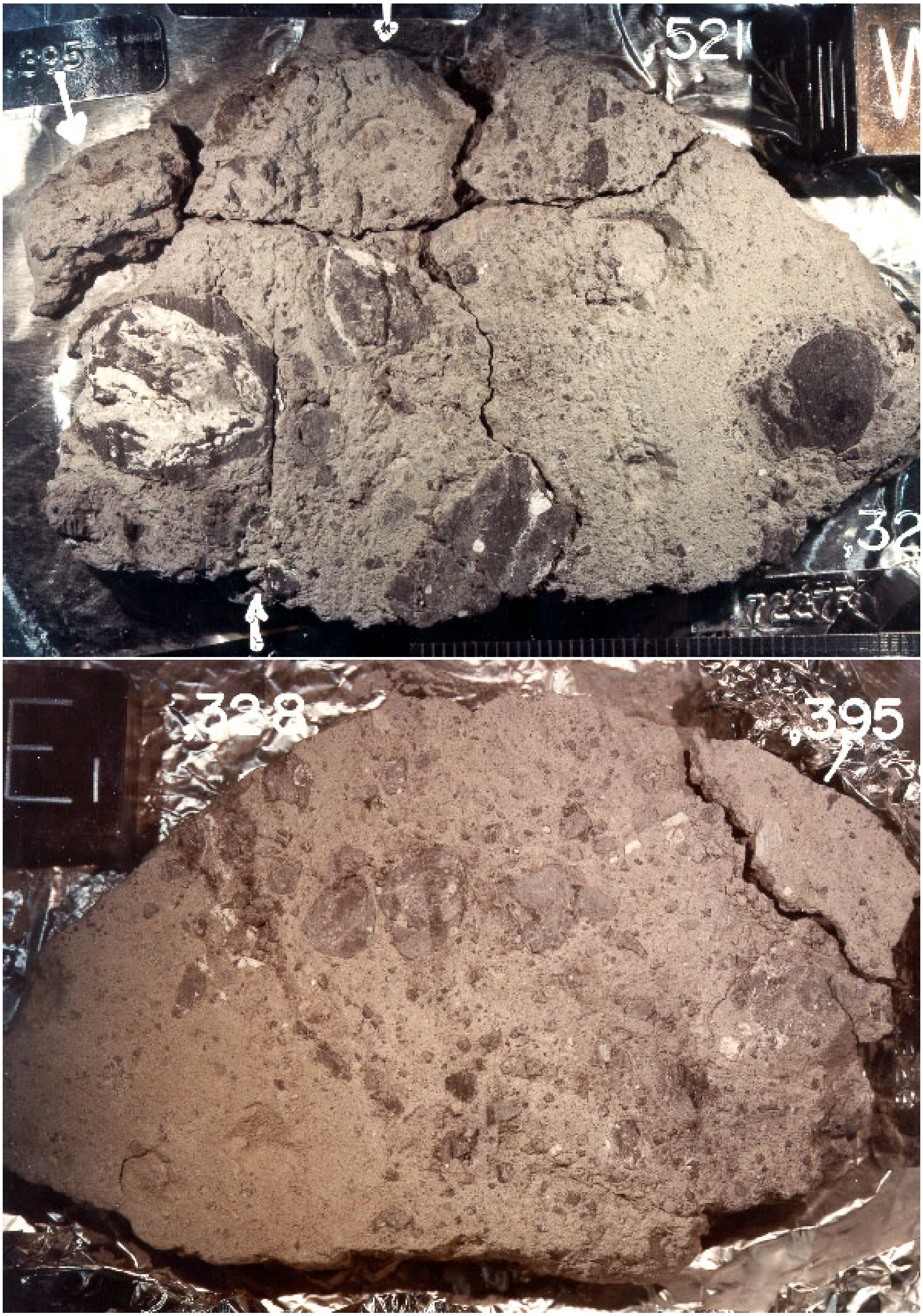

Figure 6: East and West face of slab 72275,328 prepared for Taylor consortium, 1984. NASA # S84-45542 and S85-29430. Cube is 1 inch. The “Marble Cake” clast studied by the Consortium Indomitabile is seen in this slab as well.

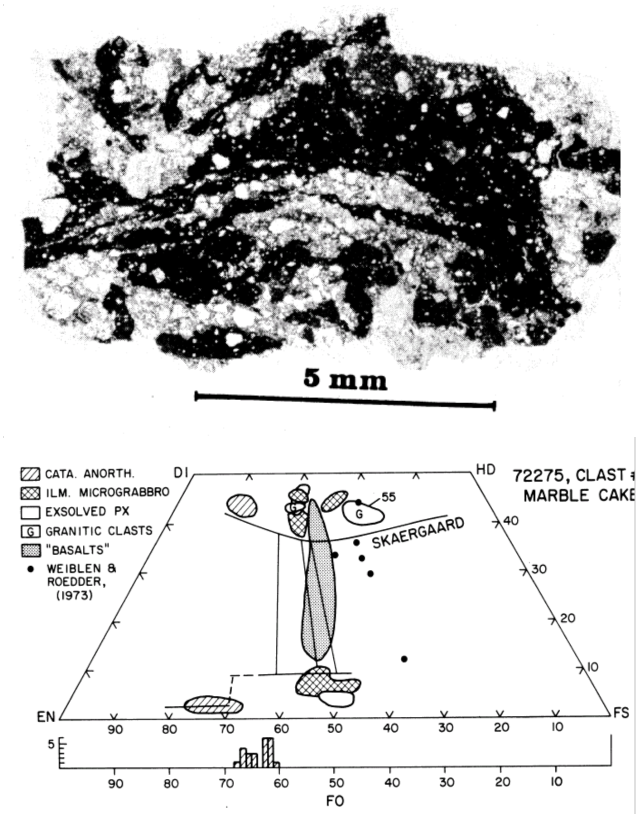

Figure 7: Thin section photomicrograph and pyroxene quadrillaterile for Marble Cake clast (from Consortium Indomitabile vol 2).

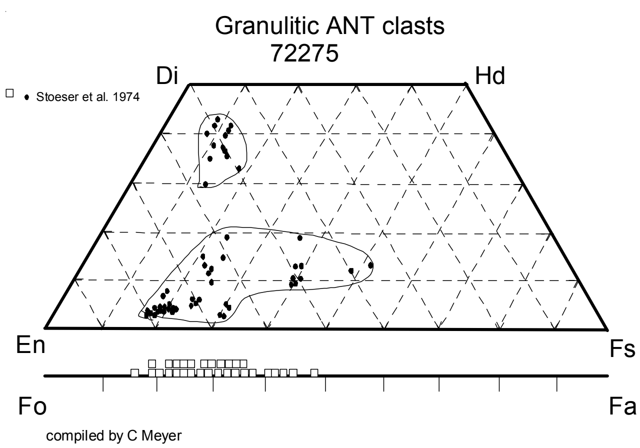

Figure 8: Pyroxene and olivine composition of small ganulitic feldspathic clasts in 72275 (from Salpas et al. 1988).

compositions of olivine and pyroxene mineral fragments in the matrix are given in figure 4.

The dark grey aphanitic clasts are dense and themselves microbreccias (see clasts 2 and 3 below) and equivalent to the majority of the material in the other samples of the boulder (72215, 72235, 72255).

A light colored zone through the sample is made up almost entirely of crushed non-mare basaltic material. The non-mare basalt clasts are fine-grain pigeonite basalts (equivalent to KREEPy basalt), with about equal amounts of pyroxene and plagioclase (figure 10).

There are a number of other rock types present in the clast population of 72275 including: ilmenite micrograbbro, pink spinel troctolite basalt, granulitic feldspathic clasts and at least one ferroan anorthosite (otherwise rare for Apollo 17) (Ryder et al. 1975, Salpas et al. 1988). Some of the larger clasts were analyzed and are discussed individually below.

Clast 1 Marble Cake
The very prominent clast known as the "Marble Cake" (seen in figure 6) is 3 cm in size with cataclastic gabbroic anorthosite and other material crudely interlayer with grey breccia and trace-element-rich, dark rim material (figure 7). The white core material is a mix of anorthositic norite, ilmenite micrograbbo, granite and other small lithic fragments with various textures. These are swirled with vesicular glass as if lightly stirred in a marble cake (Ryder et al. 1975). The black rim of the Marble Cake clast (,80) has the composition of KREEP basalt (Blanchard et al. 1975). Nunes and Tatsumoto (1975) found that their split of the marble cake clast plotted well off of the U/Pb discordia line defined by the other boulder samples.

Clasts 2 and 3 Dark gray aphanitic clasts
These large (1 cm?) dark aphanitic clasts are seen in figures 5 and 6. Blanchard et al. (1975) found that clast 2 (,83) had a trace element pattern similar to KREEP, but Morgan et al. (1975) determined 3.44 ppb Ir (non pristine). Leich et al. (1975) obtained an Ar release pattern, but could not determine the age.

Clast 4 Pigeonite Basalt (,170)
Pigeonoite basalts (later termed KREEPy Apollo 17 basalts) have equal amounts of pyroxene and plagioclase and are trace element rich. Compston et al. (1975) and Nunes and Tatsumoto (1975) studied the same pigeonite basalt (there is some confusion as to which clast this is). Compston et al. obtained an isochron age (figure 15).

Clast 5 Pigeonite Basalt (,91)
Blanchard et al. (1975), Morgan et al. (1975) analyzed another pristine clast of pigeonite basalt (figure 12). Ryder et al. (1977) and others have studied these non-

Figure 9: Thin section photomicrograph of typical KREEPy "pigeonite basalt in 72275.

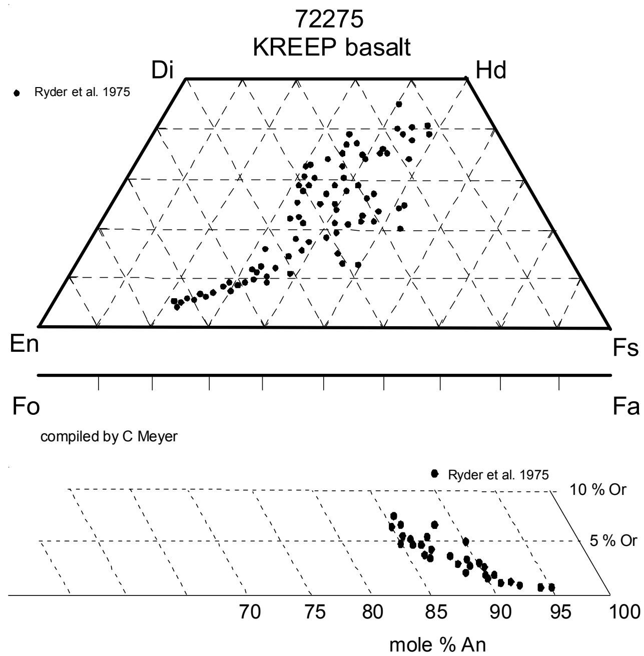

Figure 10: Pyroxene and plagioclase composition in pigeonite basalt clast (KREEP). Data replotted from Ryder et al. (1975). Similar data can be found in Salpas et al. (1987).

mare basalts in detail and determined their mineralogy (figure 10). Unlike the Apollo 14 and 15 non-mare basalts, the "pigeonite basalts" in 72275 do not have orthopyroxene cores. Leich et al. (1975) determined an Ar release plateau, but were not able to determine an age.

KREEP basalt clasts

Ryder (1977) and Salpas et al. (1987) describe several KREEP basalt clasts, several of which had a subophitic basaltic texture (figure 9). They equate these to the KREEPy pigeonite basalt clasts previous studied. A

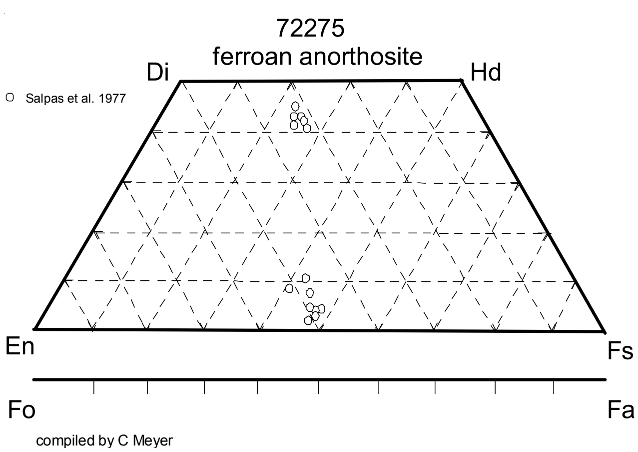

Figure 11: Pyroxene in feldspathic clast in 72275 (from Salpas et al. 1988).

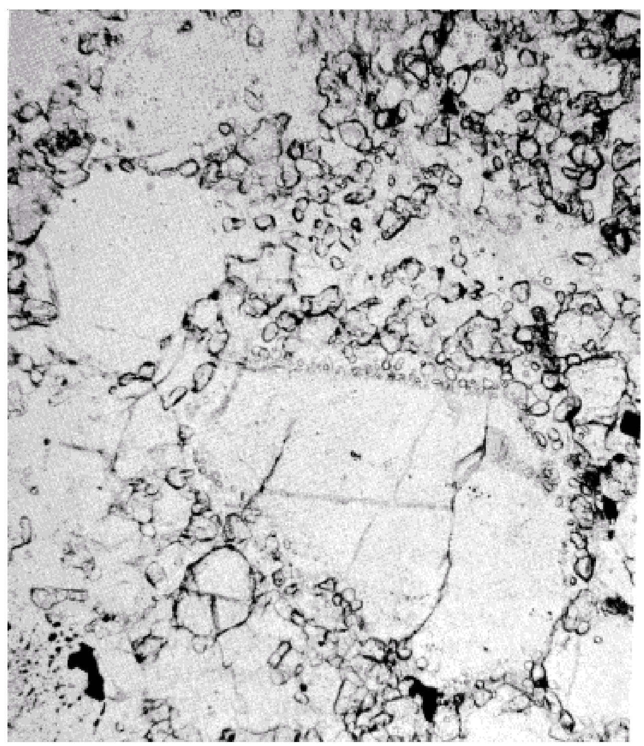

Figure 12: Thin section photomicrograph of granulitic fledspathic clast in 72275 (borrowed from Consortium Indomitabile). The figure illustrates calcic plagioclase sorrounded by mafic minerals (see figure 8).

Table 1. Chemical composition of 72275 matrix.

reference	LSPET 73		Rose 74		Hubbard 74		Blanchard 75		Morgan 75		Jovanovic 75	Salpas 87			
weight	,2		,90		,2		,57					,413	,417	,423	
SiO2 %	47.54	(a)	47.31	(f)			48.3								
TiO2	0.91	(a)	0.94	(f)			1								
Al2O3	17.01	(a)	16.9	(f)			16.3								
FeO	11.58	(a)	12.45	(f)			11.9					14.5	15.05	15.16	(d)
MnO	0.18	(a)	0.19	(f)			0.17								
MgO	9.35	(a)	9.47	(f)			10.3								
CaO	11.71	(a)	11.72	(f)			11					10.1	10.3	12.1	(d)
Na2O	0.38	(a)	0.35	(f)	0.36	(c)	0.44					0.42	0.38	0.37	(d)
K2O	0.28	(a)	0.22	(f)	0.28	(b)	0.25								
P2O5	0.35	(a)	0.38	(f)											
S %	0.08	(a)													
sum															
Sc ppm			40	(f)			44.7	(d)				45.7	48.6	49.8	(d)
V			75	(f)											
Cr			2330	(f)			2395	(d)				3062	3088	3255	(d)
Co			37	(f)			30.4	(d)				31.3	33.3	35.3	(d)
Ni	67	(a)	127	(f)			75	(d)	95	(e)		12	55	<110	(d)
Cu			5.4	(f)											
Zn	3	(a)							2.7	(e)					
Ga			3.2	(f)											
Ge ppb									406	(e)					
As															
Se ppb									34	(e)					
Rb	8.7	(a)	4.6	(f)	8.97	(b)			5.9	(e)		13	12	14	(d)
Sr	121	(a)	135	(f)	123	(b)						138	93	<160	(d)
Y	129	(a)	88	(f)											
Zr	613	(a)	545	(f)	605	(b)						600	765	700	(d)
Nb	32	(a)	24	(f)											
Mo															
Ru															
Rh															
Pd ppb															
Ag ppb									0.74	(e)					
Cd ppb									13	(e)					
In ppb															
Sn ppb															
Sb ppb									1.17	(e)					
Te ppb									4.14	(e)					
Cs ppm									0.255	(e)		0.37	0.4	0.44	(d)
Ba			330	(f)	350	(b)						370	400	400	(d)
La			35	(f)	41	(b)	50.5	(d)				47.9	50.2	52.3	(d)
Ce					106	(b)	130	(d)				129	133	139	(d)
Pr															
Nd					67.4	(b)						80	81	85	(d)
Sm					18.8	(b)	24.6	(d)				22.2	23.5	25.5	(d)
Eu					1.49	(b)	1.57	(d)				1.62	1.66	1.68	(d)
Gd					23.4	(b)									
Tb							4.9	(d)				4.59	4.97	5.1	(d)
Dy					23.2	(b)									
Ho															
Er					13.7	(b)									
Tm															
Yb			9.2	(f)	11.6	(b)	15	(d)				13.5	13.9	13.1	(d)
Lu					1.71	(b)	2.01	(d)				1.73	1.8	1.9	(d)
Hf					14.6	(b)	16.5	(d)				16.4	17.2	17.9	(d)
Ta							1.7	(d)				1.55	1.66	1.58	(d)
W ppb															
Re ppb									0.225	(e)					
Os ppb															
Ir ppb									2.26	(e)		<2	<2	<2	(d)
Pt ppb															
Au ppb									0.82	(e)		<5	<7	<6	(d)
Th ppm					5.29	(b)						5.52	5.46	6.01	(d)
U ppm					1.56	(b)			1.5	(e)	1.6	1.3	1.58	1.26	(d)

technique: (a) XRF, (b) ID/MS, (c) AA, (d) INAA, (e) RNAA, (f) varied

Table 2. Chemical composition of clasts in 72275.

	anorthosite		pigeonite basalt					marble cake		KREEP basalt			granulite	
reference	Salpas 88		Blanchard 75		Morgan 75		Blanchard 75			Salpas 87			Salpas 88	
weight	FAN ,350		PB ,91		PB ,91		clast,80	clast 1		,385	,357	,427b	,397	,433
SiO2 %			48	(a)			47	47	47		51.3	48.3		
TiO2			1.4	(a)			1.8	1.1	1.8		1.54	1.2	0.22	0.15
Al2O3			13.5	(a)			17.9	18.2	23.5		14.5	12.5	26.2	24.6
FeO	0.485	(a)	15	(a)			10.3	10.9	7.4	15.18	13.9	16.5	5.71	5.1
MnO			0.156	(a)			0.104	0.17	0.08		0.17	0.22		
MgO			10	(a)			9.43	9.14	5.24		6.8	11.4	7.9	8
CaO	19.2	(a)	10.5	(a)			11.7	11.2	14.2	9.1	10.8	9.5	14.8	14.2
Na2O	0.456	(a)	0.29	(a)			0.39	0.63	0.36	0.35	0.51	0.415	0.353	0.362
K2O			0.25	(a)			0.47	0.49	0.32					
P2O5														
S %														
sum														
Sc ppm	1.12	(a)	61	(a)			34	26.3	25	50	51	45.5	7.81	8.24
V											97	135	20	24
Cr	46.6	(a)	3147	(a)			3147			3170	1960	4420	842	881
Co	0.44	(a)	37	(a)			28	22.5	18.7	35.1	30.9	46.4	39.3	30.6
Ni	<7	(a)			43	(b)		130		50	<80	112	455	422
Cu														
Zn					2.7	(b)								
Ga														
Ge ppb					1290	(b)								
As														
Se					0.23	(b)								
Rb					8	(b)				14	12	12		
Sr	205	(a)								93	92	98	160	160
Y														
Zr										800	610	540		
Nb														
Mo														
Ru														
Rh														
Pd ppb														
Ag ppb					0.58	(b)								
Cd ppb					8.3	(b)								
In ppb														
Sn ppb														
Sb ppb					2.87	(b)								
Te ppb					7.8	(b)								
Cs ppm	0.016	(a)			0.355	(b)				0.55	0.4	0.3	0.19	0.23
Ba	40	(a)								440	500	365	72	87
La	0.567	(a)	48	(a)			78	78	48	52.5	61.7	46.2	3.66	4.72
Ce	1.48	(a)	131	(a)			213	206	131	140	155	121	10.1	12.6
Pr														
Nd	<2.5	(a)								92	108	75	5.7	6.2
Sm	0.228	(a)	23	(a)			36	36	22.5	23.8	28.9	22.3	1.56	1.93
Eu	0.928	(a)	1.58	(a)			2.14	2.1	1.81	1.62	1.87	1.45	0.835	0.86
Gd														
Tb	0.045	(a)	4.5	(a)			7.7	7.7	4.7	4.9	5.82	4.31	0.375	0.49
Dy														
Ho														
Er														
Tm														
Yb	0.125	(a)	11.9	(a)			24	25.4	13.9	13.8	15.5	12.4	1.69	2.06
Lu	0.02	(a)	1.75	(a)			3.5	3.5	2.04	1.83	2.18	1.67	0.238	0.292
Hf	0.133	(a)	18	(a)			19.8	25.1	14	17.4	20.5	15.9	1.46	1.98
Ta	0.015	(a)						3.5		1.62	1.9	1.37	0.302	0.309
W ppb														
Re ppb					0.007	(b)								
Os ppb														
Ir ppb	<2	(a)			0.023	(b)				<2			16.4	14
Pt ppb														
Au ppb	<0.8	(a)			0.045	(b)				<7			6.8	6.5
Th ppm	0.047	(a)						12.8		5.98	6.73	5.25	1.17	2.06
U ppm	0.02	(a)			1.5	(b)				1.3	1.95	1.45	0.34	0.37
technique	*(a) INAA, (b) RNAA*													

large number of these clasts, including two with pristine igneous texture, were analyzed by Salpas et al. (1987). Shih et al. (1992) were able to obtain one of the brecciated KREEP basalt clasts and date it by both Rb-Sr and Sm-Nd (figures 16 and 17).

Ferroan Anorthosite Clast (,350)
A unique fragment of pristine ferroan anorthosite was studied by Salpas et al. (1988). It was 3 x 4 x 5 mm and composed of 95% plagioclase (An_{96}) and 5% pyroxene (figure 12). The chemical composition is given in table 2 and this clast is apparently plutonic and pristine (Ir<2 ppb). Since this is what we think the lunar crust was made of, we are surprised to not find more fragments of this kind in the ejecta of large impacts.

Granulitic ANT Clasts
The Consortium Indomitabile coined the acronym ANT for the small fragments of plagioclase-rich, potash and phosphorous-poor rocks whose mineralogies vary over the range anorthosite-norite-troctolite (*never mind the otherwise small grain size*). In 72275 the textures of these feldspathic clasts are that of an annealed granulite (figure 12). Salpas et al. (1988) discovered several that were large enough to analyze (table 2, figure 13). However, they were all high in Ir.

Mineralogy
The mineral fragments in the matrix are, in order of abundance: plagioclase, olivine, orthopyroxene, pigeonite, Ca-rich clinopyroxene, ilmenite, spinel, cristobalite, barian K-feldspar, Fe metal, troilite, zircon and armalcolite (Stoeser et al. 1974).

Chemistry
Chemical analyses of the matrix of 72275 are given in table 1 and of selected clasts in table 2. In addition there are a number of analyses of small clasts in thin section by broad-beam, electron probe microanalyses in the papers by Ryder et al. (1975) and Stoeser et al. (1975). Salpas et al. (1987, 1988) present the analyses of a large number of clasts (mostly KREEP basalt and granulitic feldspathic clasts (ranges shown in figure 13).

The composition of the light matrix of 72275 is broadly similar to that of the pigeonite basalt clasts (Salpas et al. 1987). There is a hint of slightly elevated Al, which would be expected by the presence of anorthositic clasts.

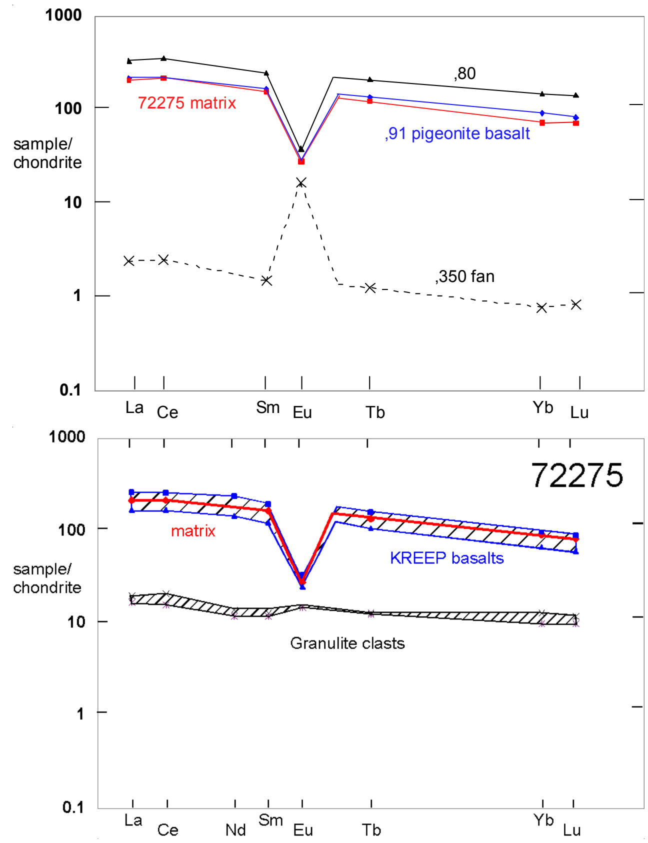

Figure 13: Normalized rare-earth-element diagram for matrix and selected clasts in breccia sample 72275. Data for matrix and pigeonite basalt is from Blanchard et al. (1975), and for clasts Salpas et al. (1987, 1988).

The trace siderophile element ratios (Morgan et al. 1975) are not exactly what is expected for Serenitatis ejecta. Ge is very high, and there is evidence that this is from the high KREEP component (which is itself surprisingly high in Ge).

Radiogenic age dating
Compston et al. (1975) and Shih et al. (1992) found that the age of the KREEPy basalt clasts in 72275 to be about 200 m.y. older than the ages of KREEP basalts from Apollo 15 (such as 15382, 15386). Nunes and Tatsumoto (1975) attemped to date various chips of 72275 for the consortium by U-Th-Pb, but learned instead that the breccia and its clasts has suffered extensive movement of Pb. Leich et al. (1975) also attempted to obtain Ar-Ar dates, but found that plateau ages were ill defined except for one case. *(please note that dates reported here are the original data and require correction for new decay constants)*

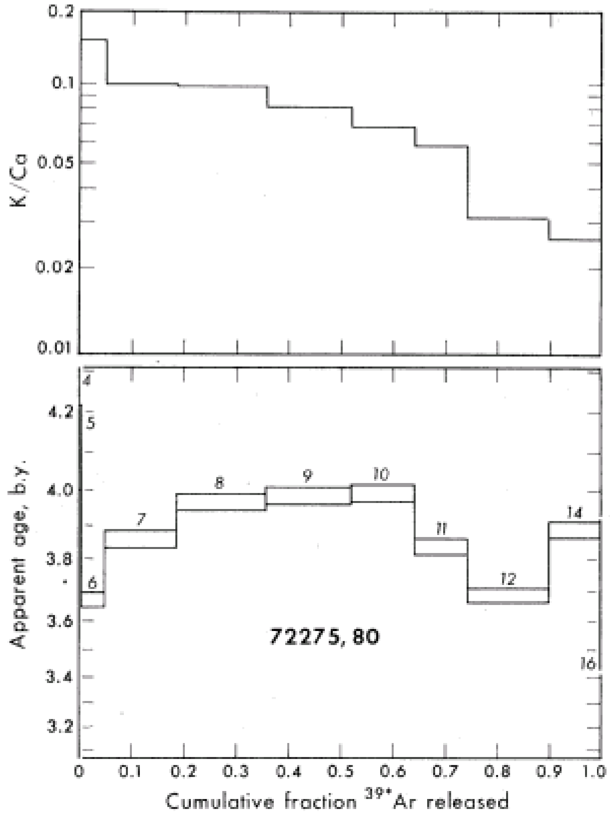

Figure 14: Ar-Ar release pattern for 72275,80. Plateau age is 3.99 +/- 0.03 b.y. (from Leich et al. 1975).

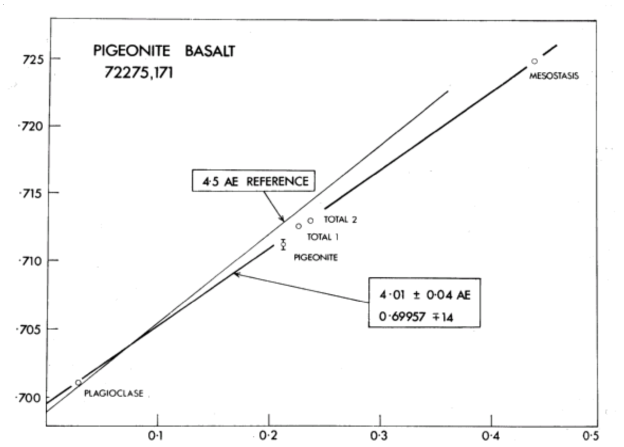

Figure 15: Rb-Sr isochron diagram ofr pigeonite clast in 72275 (from Compston et al. 1975).

Cosmogenic isotopes and exposure ages

Leich et al. (1975) determined the exposure age of 72275 and other samples of the same boulder by a number of techniques, of which ^{81}Kr are the most reliable (figure 18). The conclusion is that 72275 (from the top of the boulder) has been exposed to cosmic rays for 52.5 ± 1.4 m.y.

Other Studies

Pearce et al. (1974), Brecher et al. (1974) and Banerjee and Swits (1975) determined the magnetic properties of 72275. Housley et al. (1977) included 72275 in their study of ferromagnetic resonance of lunar samples (it had none).

Goswami and Hutcheon (1975) and Goswami et al. (1977) studied the track densities in minerals from 72275. Charette and Adams (1977) have reported the spectra.

Processing

72275 is friable and broke into pieces on the return to Earth (figure 1). A partial slab (,42) was cut to expose the prominent clast for the Consortium Indomitabile in 1974. This saw cut was completed and two additional slabs were cut for the Larry Taylor breccia-pull-apart project in 1984.

Summary of Age Data for 72275

	Ar-Ar	Rb-Sr	Sm-Nd	
Leich et al. 1975	3.99 ± 0.04 b.y.			Rim of Marble Cake
Compston et al. 1975		4.01± 0.04		Pigeonite basalt ,171
Shih et al. 1992		4.13 ± 0.08	4.08 ± 0.07	KREEP basalt clast B-1

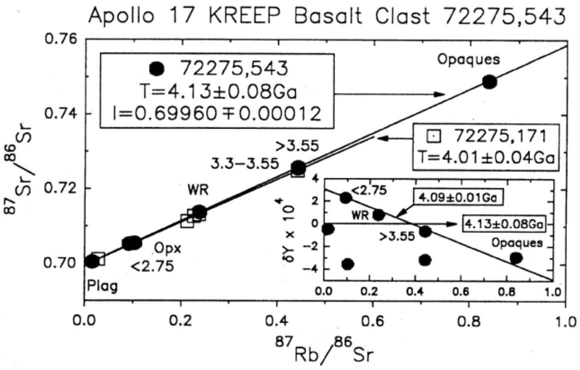

Figure 16: Rb-Sr isochron diagram for KREEP basalt clast in 72275 (from Shih et al. 1992).

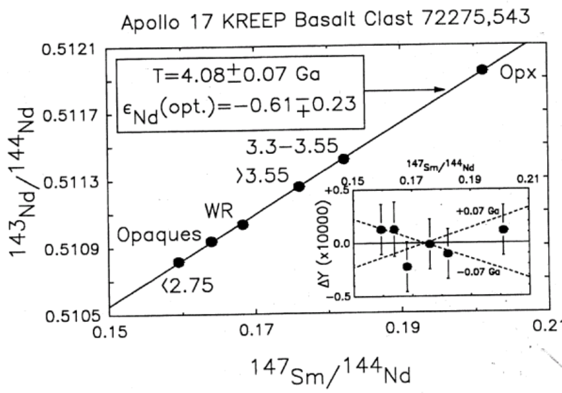

Figure 17: Sm-Nd isochron diagram for KREEP basalt clast in 72275 (from Shih et al. 1992).

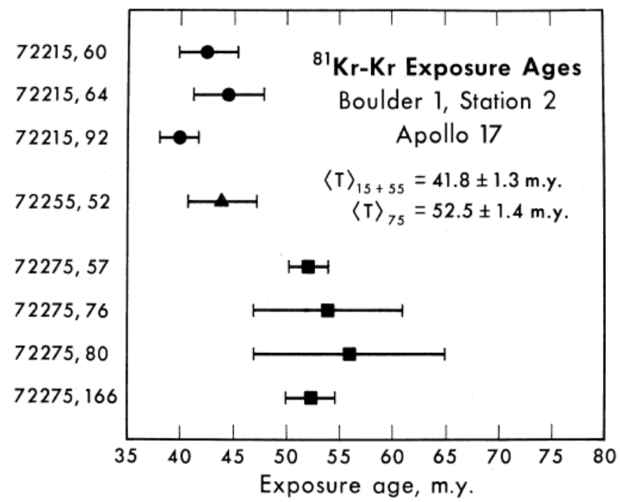

Figure 18: Exposure ages by the Kr81 method from Leich et al. 1975.

Flow Diagram